

Intro & Cameras

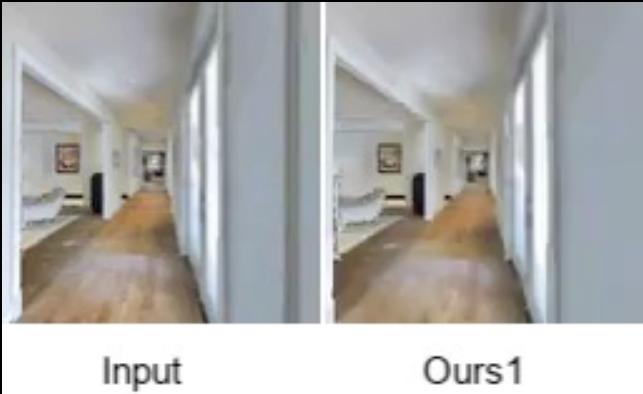
EECS 442 – Jeong Joon Park
Winter 2024, University of Michigan

Jeong Joon “JJ” Park – 3D Vision & Generative Models



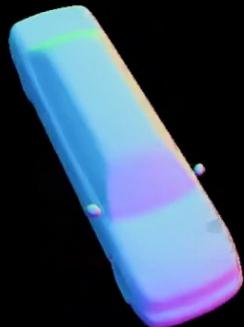
Input Video

Estimating Scene Physical Properties



Input

Ours1



Learned Car Shape Space

Neural 3D Representation



3D Generative Model

Scene Generation



Novel-View Synthesis



Messy Scene

Cleaned “Regular” Scene

Welcome!

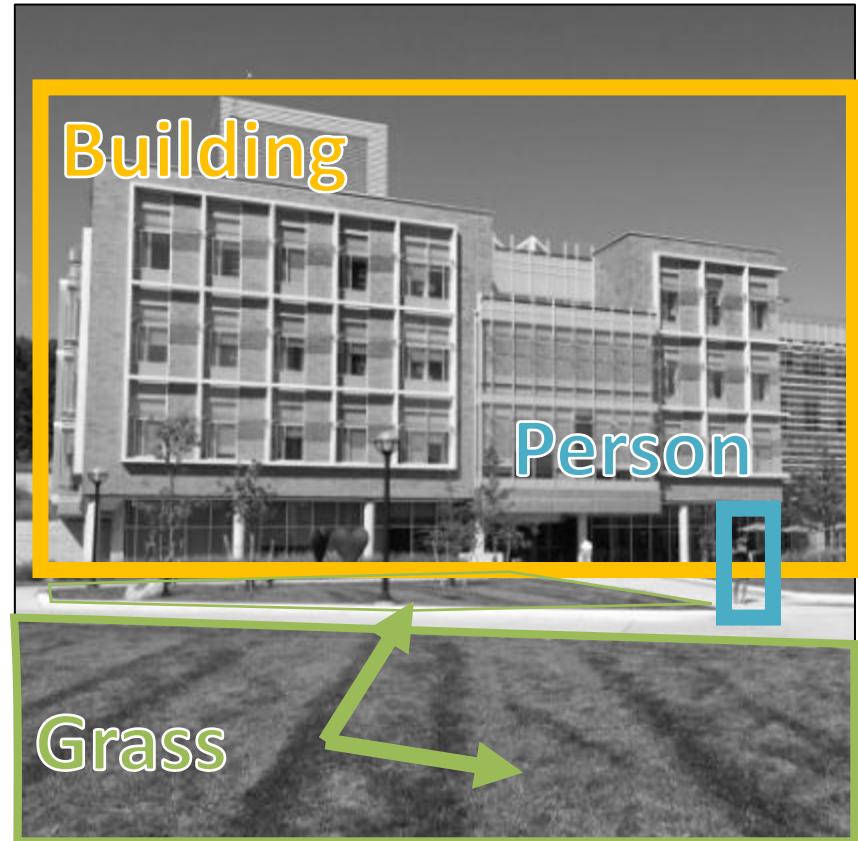
Basic Concepts of Computer Vision
Course Largely Following Previous Ones by
Profs. Fouhey and Johnson

Goals of Computer Vision

Get a computer to understand



Goal: Naming

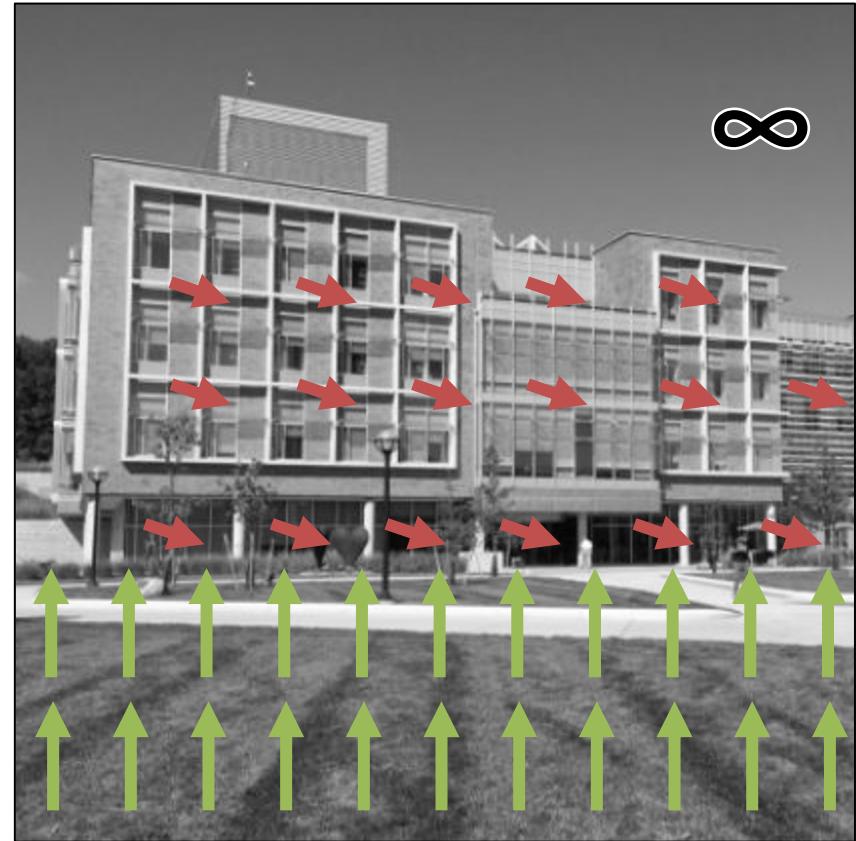


Goal: Naming



The picture shows a building with many windows and grass in front of it. There is a person walking on the right...

Goal: 3D



Goal: Actions



Seems Obvious, Right?

- **Key concept to keep in mind throughout the course:** you see with both your eyes **and** your brain.
- Which were developed over the course of evolution and your lifetime.

Why is it Hard?

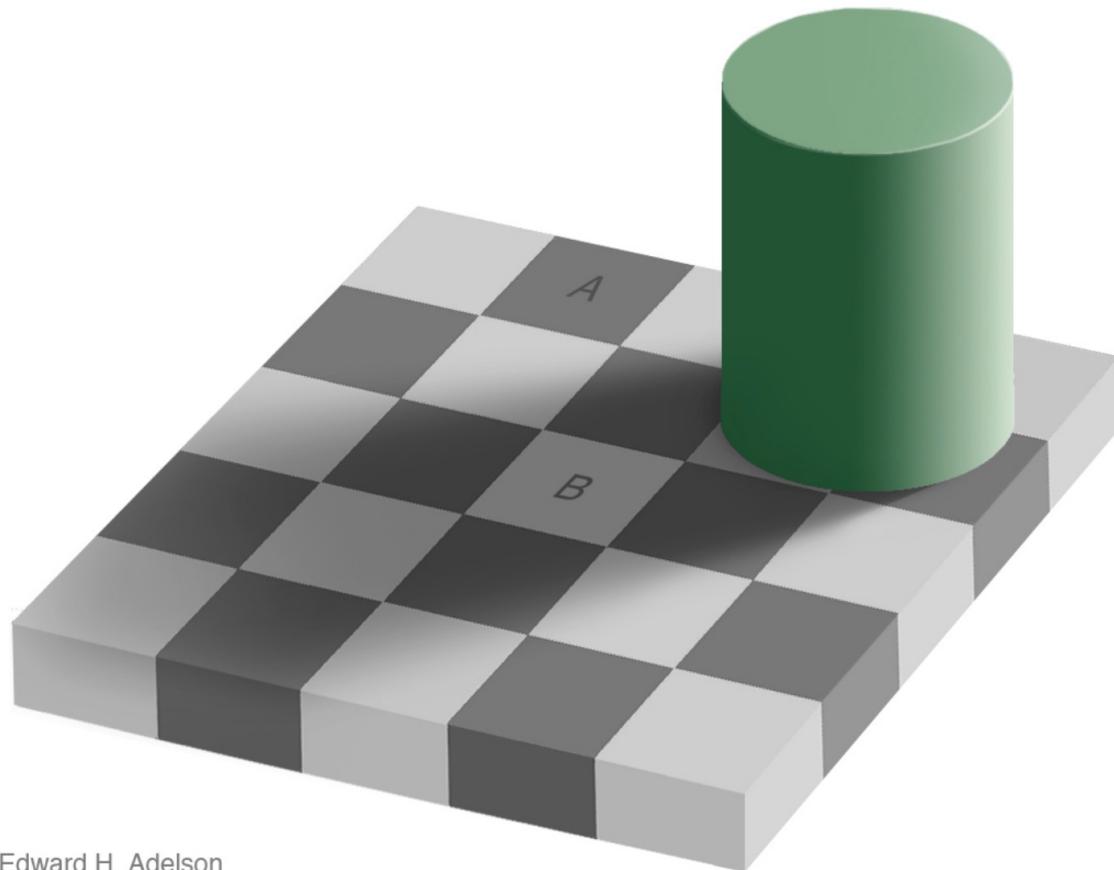


097	097	097	097	097	097	097	097	097	096	097	097	096	096	096
100	100	100	100	100	100	101	101	102	101	100	100	100	100	099
105	105	105	105	105	105	105	103	102	102	101	103	104	105	
109	109	109	109	109	110	107	118	145	132	120	112	106	103	
113	113	113	112	112	113	110	129	160	160	164	162	157	151	
118	117	118	123	119	118	112	125	142	134	135	139	139	175	
123	121	125	162	166	157	149	153	160	151	150	146	137	168	
127	127	125	168	147	117	139	135	126	147	147	149	156	160	
133	130	150	179	145	132	160	134	150	150	111	145	126	121	
138	134	179	185	141	090	166	117	120	153	111	153	114	126	
144	151	188	178	159	154	172	147	159	170	147	185	105	122	
152	157	184	183	142	127	141	133	137	141	131	147	144	147	
130	147	185	180	139	131	154	121	140	147	107	147	120	128	
035	102	194	175	149	140	179	128	146	168	096	163	101	125	

We need to invent eyes and brains to interpret list of numbers!

Finding patterns, concepts, and meanings of the world from these numbers!

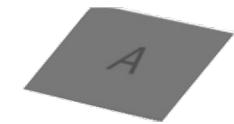
To See: Perception vs. Measurement



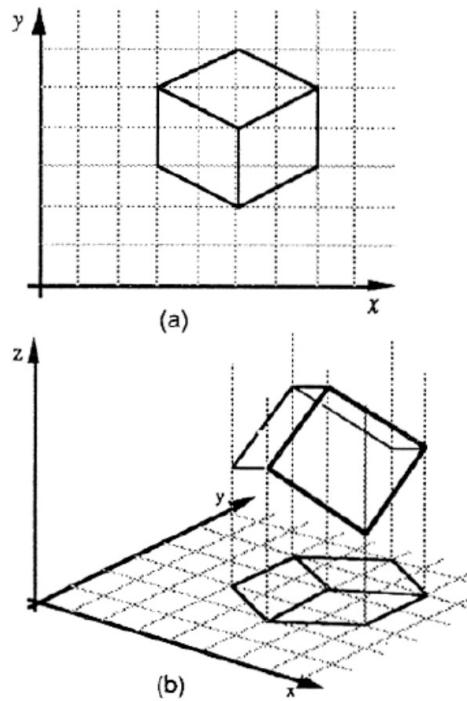
Edward H. Adelson

To See: Perception vs. Measurement

- We don't just read the numbers!



Fundamental Ambiguities (2D)



[Sinha & Adelson, 1993]

Fundamental Ambiguities

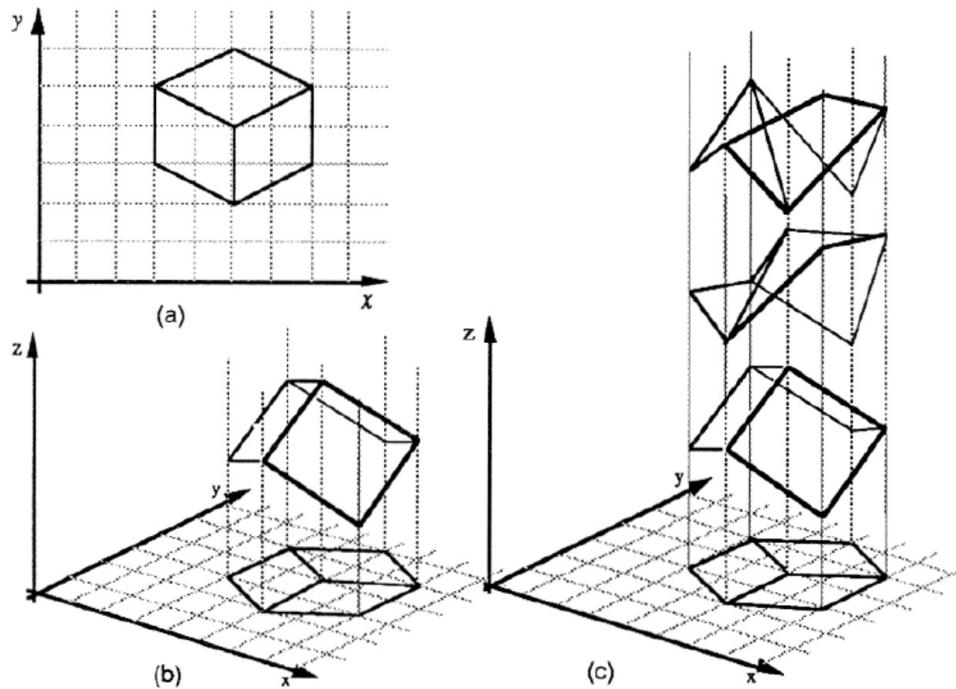


Figure 1. (a) A line drawing provides information only about the x , y coordinates of points lying along the object contours. (b) The human visual system is usually able to reconstruct an object in three dimensions given only a single 2D projection (c) Any planar line-drawing is geometrically consistent with infinitely many 3D structures.

[Sinha & Adelson, 1993]

Despite This, We've Made Progress

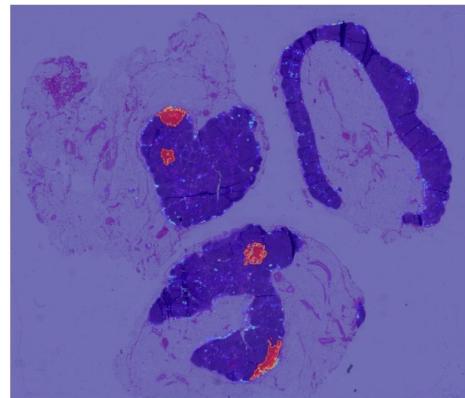
- Few of these problems are **solved** (*and there are lots of dangers to pretending things are solved when they aren't*)
- But we do have systems with performance ranging from non-embarrassing to super-human (with the right caveats)

Exciting Times for Computer Vision

Robotics



Medical applications



3D modeling



Driving



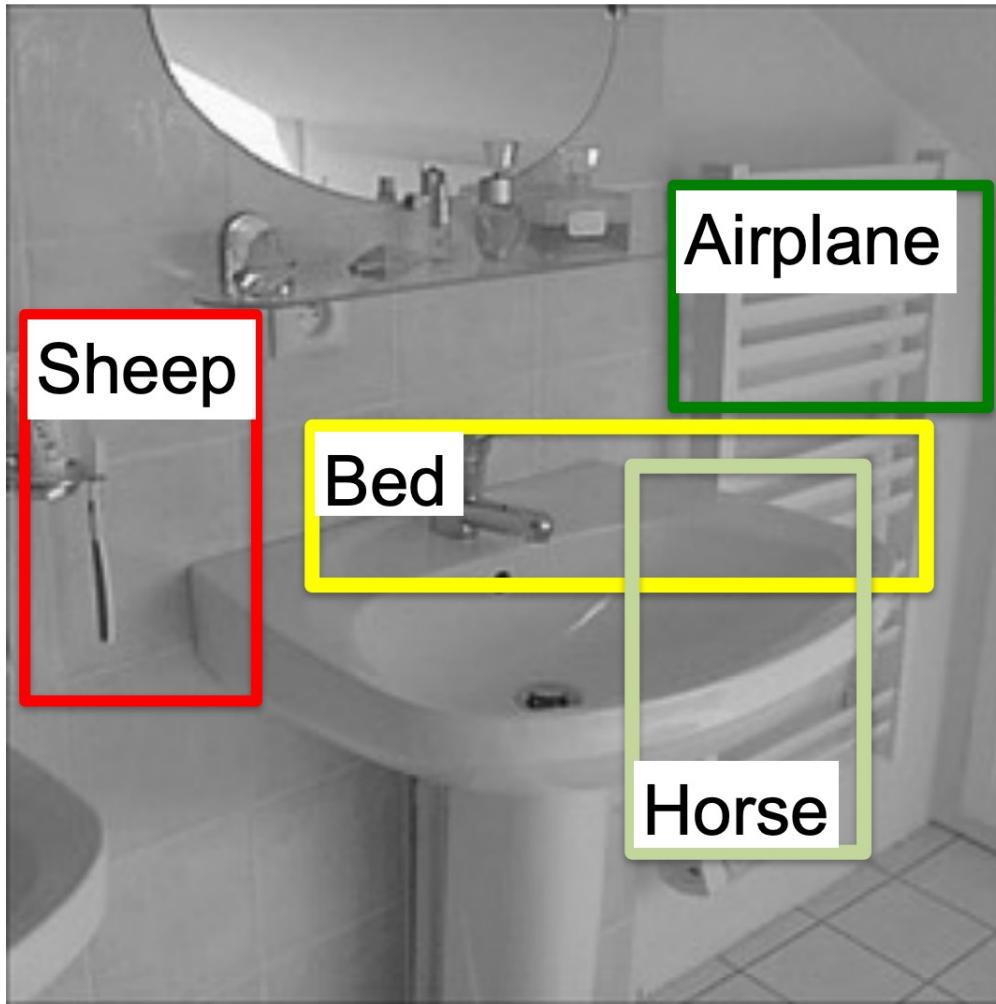
Communication



Accessibility



Object Detection Circa 2010



Object Recognition Now



Generative Models

A photo of a frog reading the newspaper named “Toaday” written on it. There is a frog printed on the newspaper too.



[Yu et al., “Parti”, 2022]

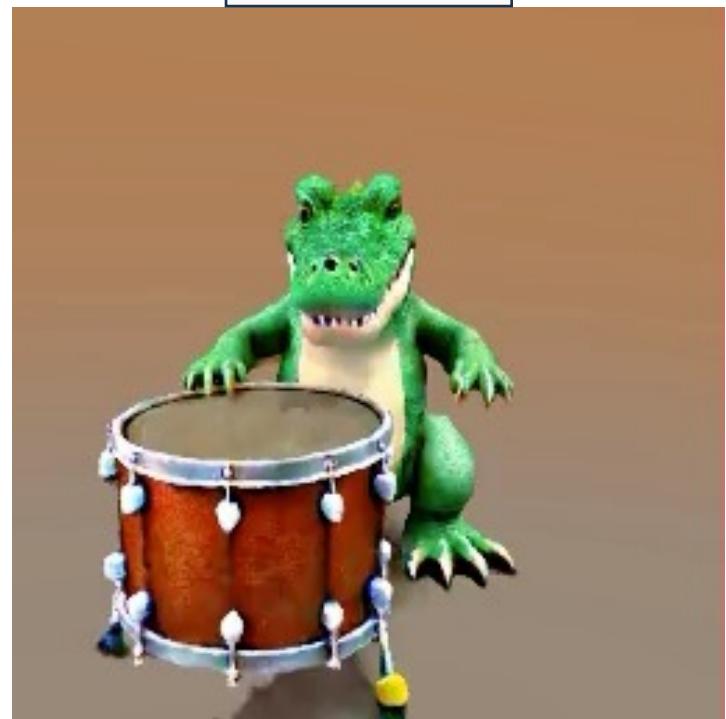
3D Generative Models

“a pig
wearing a
backpack”



[Poole et al., “DreamFusion”, 2022]

“a crocodile
playing a
drum set”



[Bahmani et al. “4D-fy”, 2023]

Robot Vision



3D Reconstruction



Barron, et al., 2023

Administrivia

Meeting and Communication

- Class: Mon/Wed 10:30AM-Noon, STAMPS In-Person and Recordings (but **please** give it a minute!)
- Discussions (6), attend **any**, starting Monday January 15th. One will be recorded. In-person. Starting next week.
- Office Hours (7 including mine, mainly virtual) will post the times on the website
- Piazza: We monitor but don't guarantee instant responses.
- Direct Email: Avoid. **Why?**

Class Size, Waitlist, Modalities

- *Thing to keep in mind:* there are 280 students, 1 professor, 6 TAs
- We cannot handle hundreds of emails.
 - + most of the questions are shared
- *Waitlist:* I'm limited by staff. I don't reorder the waitlist – each person has a good reason and it's a zero-sum game. *Contact the undergraduate advising office*

Office Hours + Piazza



Office Hours + Piazza

- ~120 hours of work available for the course across me, GSIs, IAs. Needs to cover:
 - Lectures + Discussion + Office Hours: ~25 hours of standing-there time
 - Writing, testing, debugging, and setting up grading for HW; preparing for lectures + discussions; conceptual Qs; course administration
 - Helping students learn the material + do HW
- Lining up for a personal zoom room with a GSI for debugging / debugging via piazza is inefficient and makes everyone want to tear their hair out. **Why?**

Let's Work Together

- Please watch the lectures + discussions and then do the HWs; please don't do the reverse.
- We'll try to teach you how to debug better. Debugging well is a hard skill, but it will be important for your career.
- Work together from the beginning.
- I really want to do and encourage modalities for OH that are more efficient

Zoom, Recordings, etc.

- The lectures are going to be in-person and no zoom live stream at the same time.
- Recordings may take a little bit of time to get up.
- Anticipate at least one tech screw-up during the semester

Websites

- Canvas: Links to other stuff and turning in big files
- Course website: slides, assignments, syllabus
<https://eecs442.github.io/>.
- Piazza: ask questions, answer questions
<https://piazza.com/class/lr0rfd6e5dm5wf/>
Sign Up!
- Gradescope: details later with release of HW1
<https://www.gradescope.com/courses/692514>

Evaluation

- Homework (6x10%) – five mini-project homeworks with a writeup and code
- Midterm (20%) – One in-class midterm
- Project (2% [proposal] +18% [report+presentation]) – a semester-long project done in a team

Homework Philosophy

- ***Tons*** of fantastic resources for many things so teaching you to setup pytorch or stable diffusion is a waste
- Few components remain the same in the long run. I want to teach these.
- Some work may be frustrating or hard to wrap your head around; please expect some of that
- This may be your first ULCS. Be patient and build in some transition time
- Homework \neq spec. We'll often ask you to interpolate details, figure things out, etc.

Evaluation: Homework Late Policy

- Penalty: 10% reduction per late day (max score)
- Example:
 - Due: 5pm Tuesday.
 - Submitted 4:59pm Tue: No penalty!
 - Submitted 5:15pm Tue: max score becomes 90%
 - Submitted 5:15pm Wed: max score becomes 80%
- Everyone gets 6 free late day credits, applied automatically and optimally. These waive late penalties. Assume you will need these
- Exceptions for exceptional situations. Contact us.

Copying

- Read the syllabus – don't look at peoples' code, no pair programming
- We will run MOSS
- Submit it late (*that's why we have late days*), half-working (*that's why we have partial credit*), or take the zero on the homework – I guarantee you won't care about one bad homework in a year
- If you're overwhelmed, talk to us

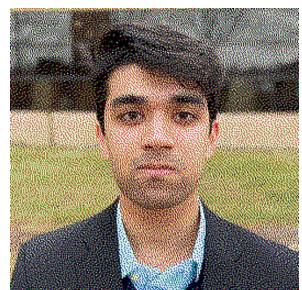
Evaluation: Term Project

- Work in a team of 3-4 to do *something cool*
- There will be a piazza thread for pairing up
- Could be:
 - Applying vision to a problem you care about
 - Independent re-implementation of a paper
 - Trying to build and extend an approach
 - An idea that we give you
- Should be 1 homeworks worth of work per person

Doing Well in 442 – Work Together



Enjoy each topic like a story. Discuss with friends about homework. Check piazza for similar questions, ask for help or get inspiring ideas on piazza as well. Go to discussions – Siyi Chen



Exchanging advice and discussing concepts with your peers is a valuable learning opportunity and something that we want you to do (as long as it's within the limits of the Honor Code) – Ahmed Khan



+1 on finding people to work with. It made the class much more enjoyable. – Jacob Skwirsk

Don't have friends in the class?

We'll introduce you to people (Check Piazza Post!)

Doing Well in 442 – Start Early



Start early. – Nikhil Devraj

R

Start early, especially for any projects using colab and gpus. – Rahul Gupta

Use Google Colab for GPU resource. There are lab machines with GPUs with the [CAEN computer labs](#)

How To Have a Bad Time in 442

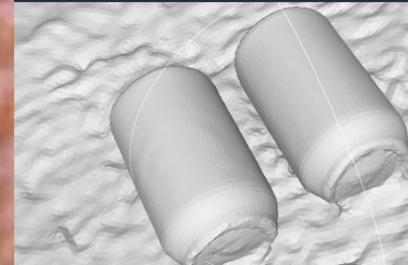
- Bad time: start homeworks with three days to go; have conceptual issues **and** debugging fun
- Bad time: ignore lectures; just-in-time lecture-watching by scrubbing through lectures while doing homeworks
- Bad time: debug by piazza + OH queue

Your Todos

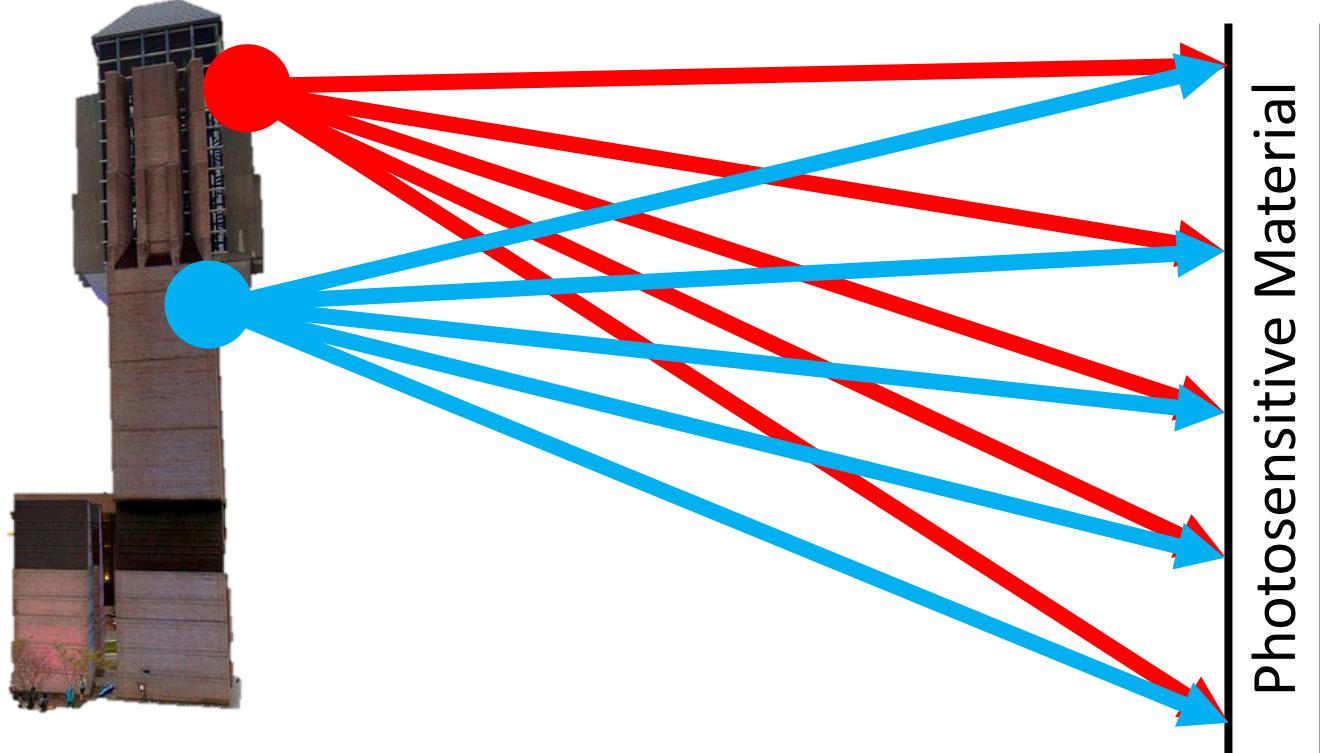
- Study buddy matching in Piazza if you'd like us to help you match
- Background poll if you'd like to help me tailor the course (and future offerings)
- Get to know you poll if you'd like
- First homework out next week. No need to do anything. Just relax

Cameras

Every Pixel Has a Reason



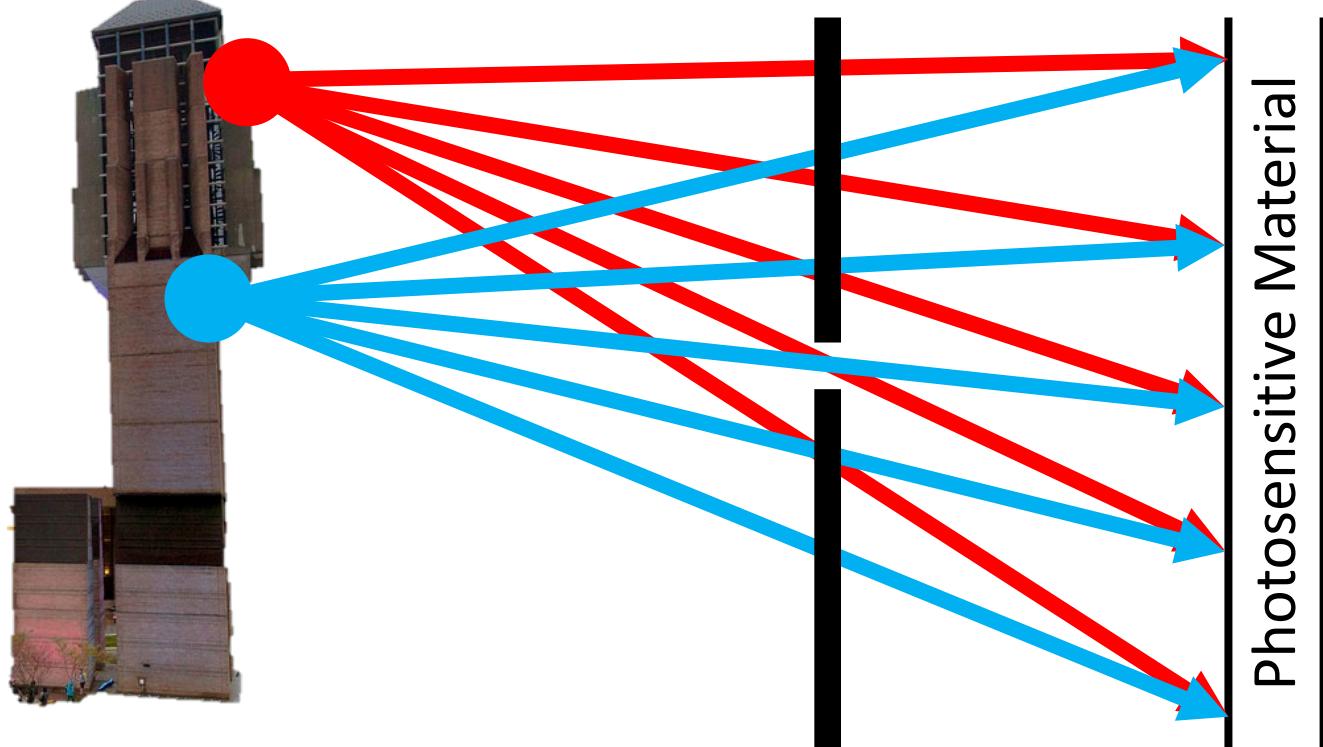
Let's Take a Picture!



Idea 1: Just use film

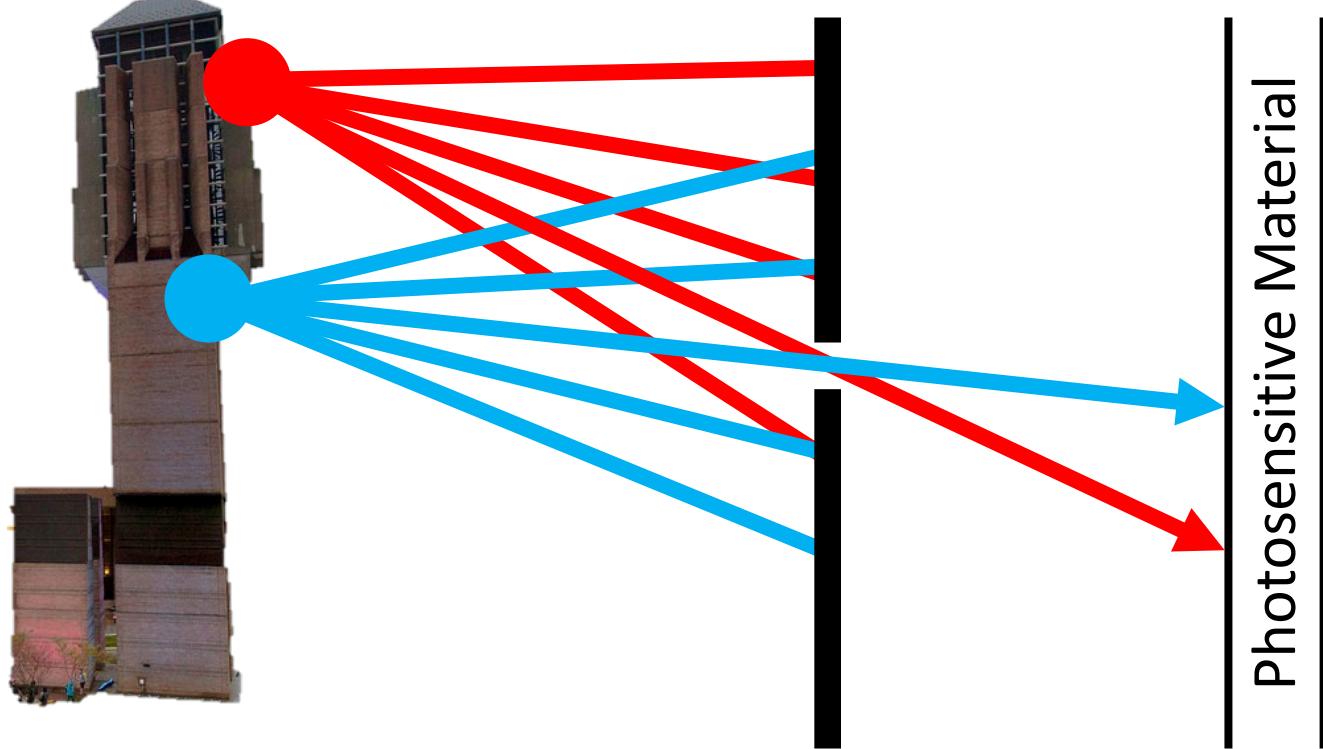
Result: Junk

Let's Take a Picture!



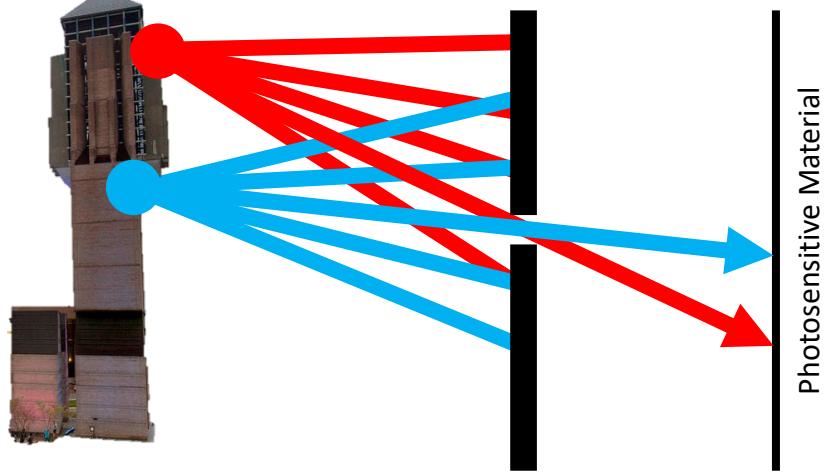
Idea 2: add a barrier

Let's Take a Picture!



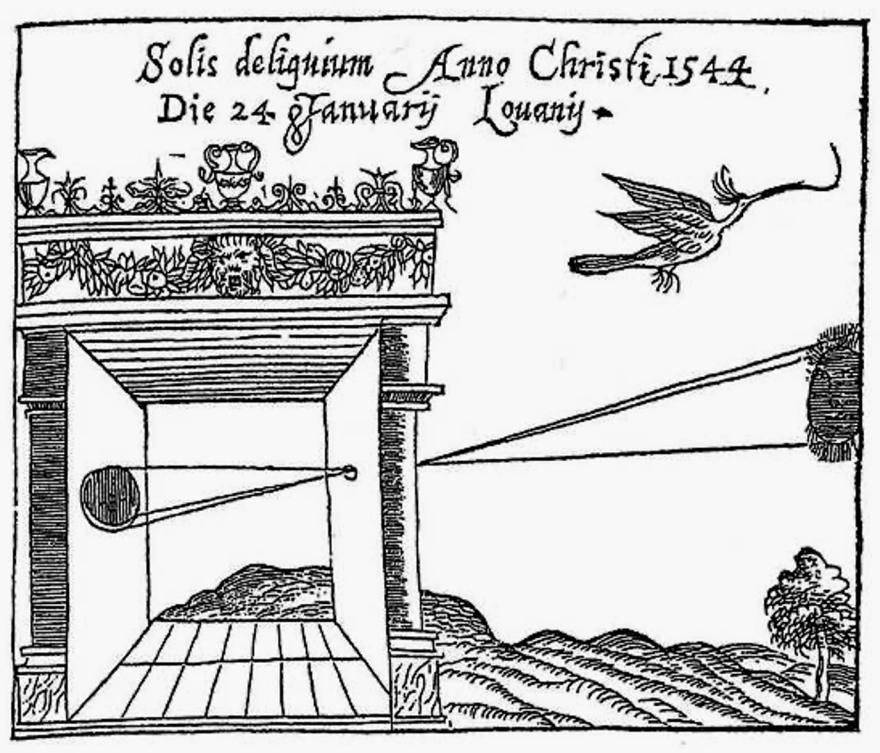
Idea 2: add a barrier

Let's Take a Picture!



Film captures all the rays going through a point (*a pencil of rays*).
Result: good in theory!

Camera Obscura



- Basic principle known to Mozi (470-390 BCE), Aristotle (384-322 BCE)
- Drawing aid for artists: described by Leonardo da Vinci (1452-1519)

Camera Obscura



Abelardo Morell, Camera Obscura Image of Manhattan View Looking South in Large Room, 1996

After scouting rooms and reserving one for at least a day, Morell masks the windows except for the aperture. He controls three elements: the size of the hole, with a smaller one yielding a sharper but dimmer image; the length of the exposure, usually eight hours; and the distance from the hole to the surface on which the outside image falls and which he will photograph. He used 4 x 5 and 8 x 10 view cameras and lenses ranging from 75 to 150 mm.

After he's done inside, it gets harder. "I leave the room and I am constantly checking the weather, I'm hoping the maid reads my note not to come in, I'm worrying that the sun will hit the plastic masking and it will fall down, or that I didn't trigger the lens."

From *Grand Images Through a Tiny Opening*, Photo District News, February 2005



Abelardomorell.com (now gone 😞)

Camera Obscura

Useful for viewing solar eclipses!

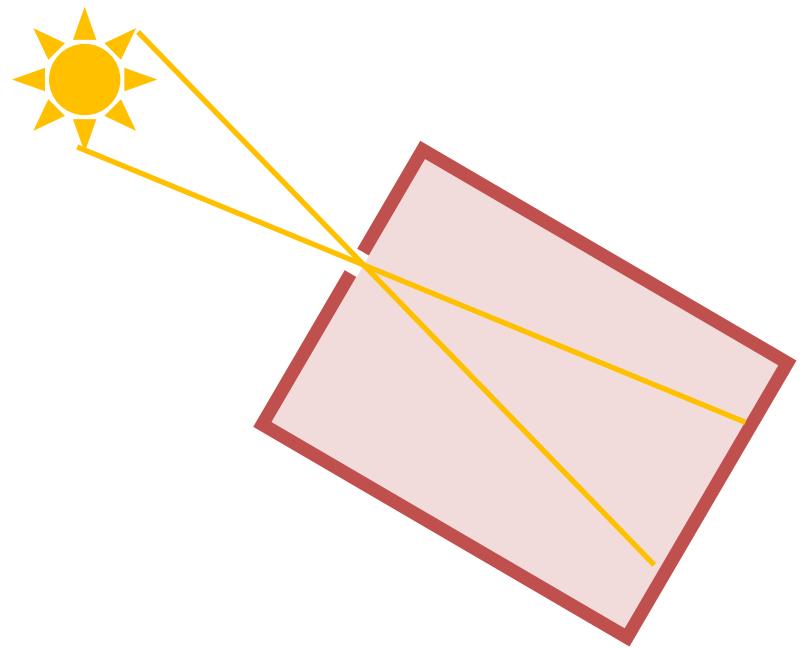
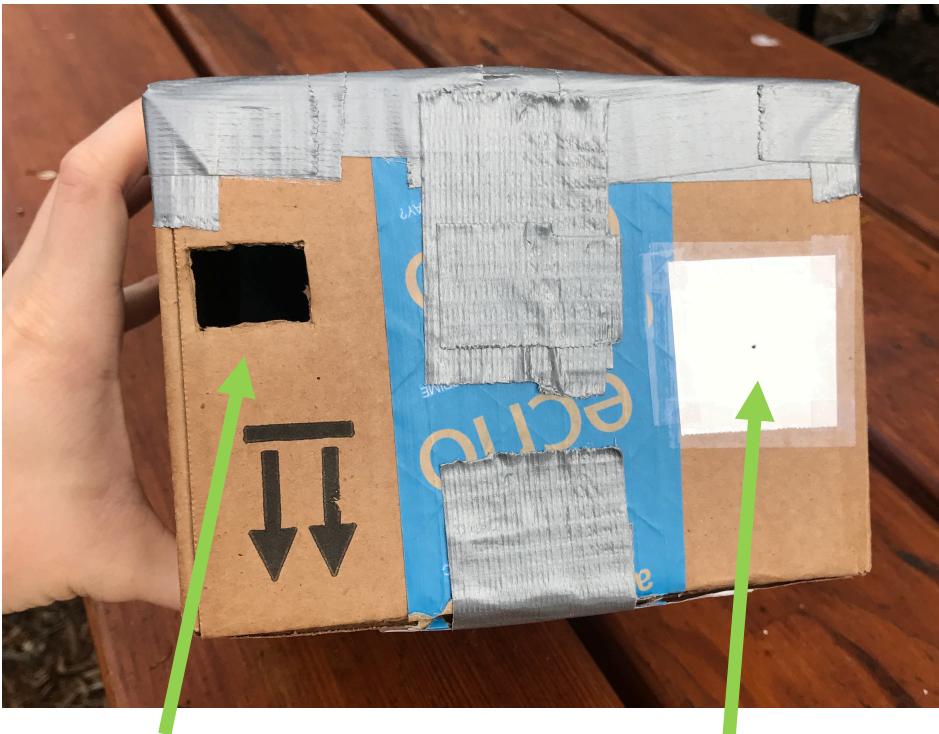
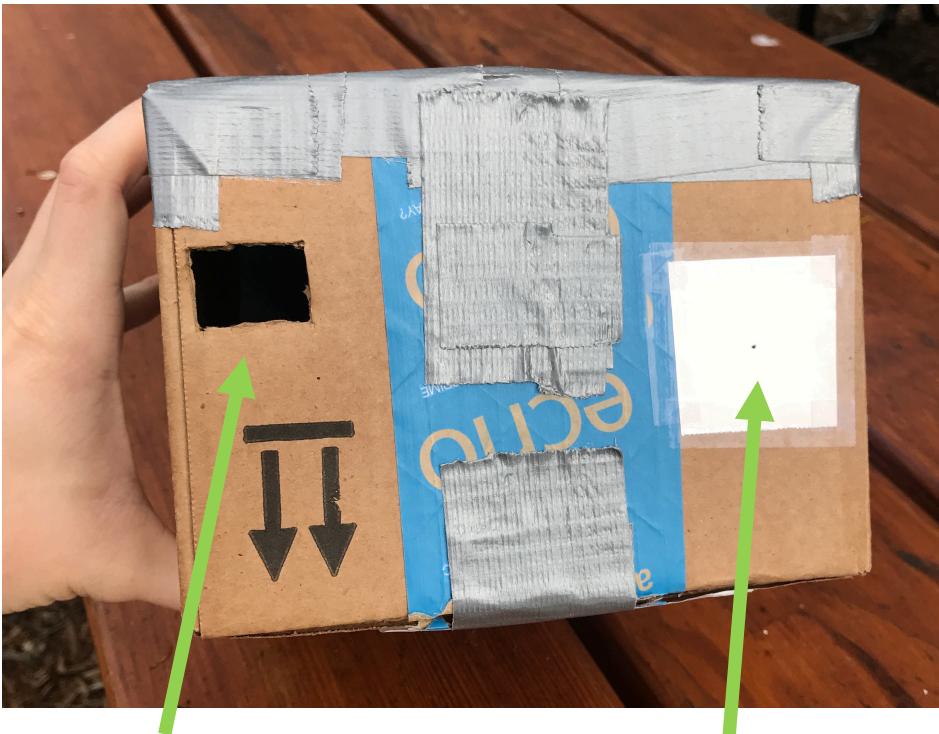


Photo Credit: Justin Johnson

Camera Obscura

Useful for viewing solar eclipses!



Put your
eye here

Pinhole: aluminum
foil with a tiny hole

Photo Credit: Justin Johnson



Justin on 8/21/2017

Camera Obscura

Useful for viewing solar eclipses!



Photo of
the sun

Photo Credit: Justin Johnson

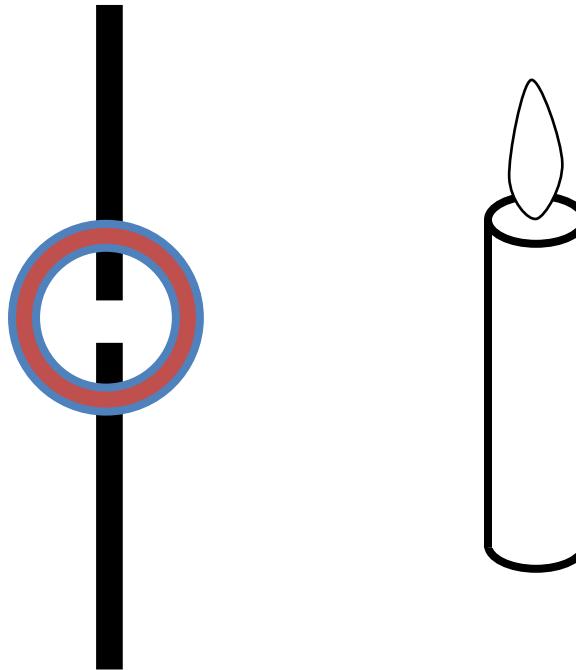
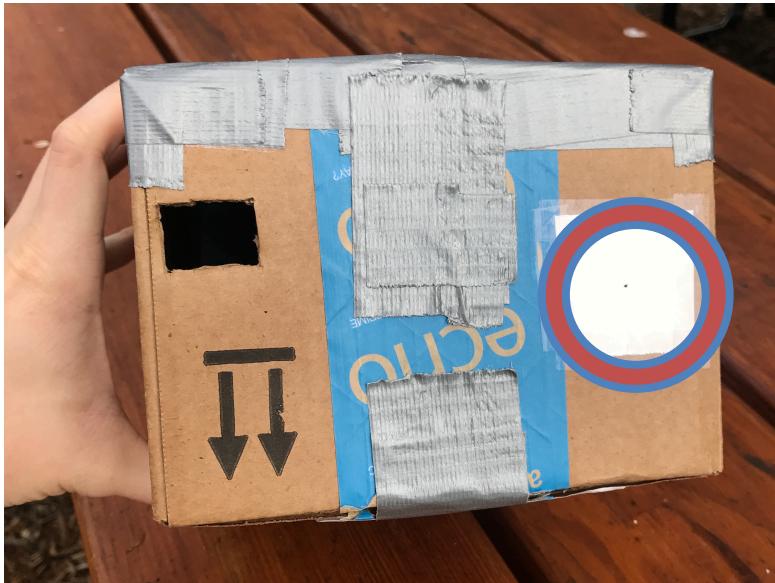


View in
the box

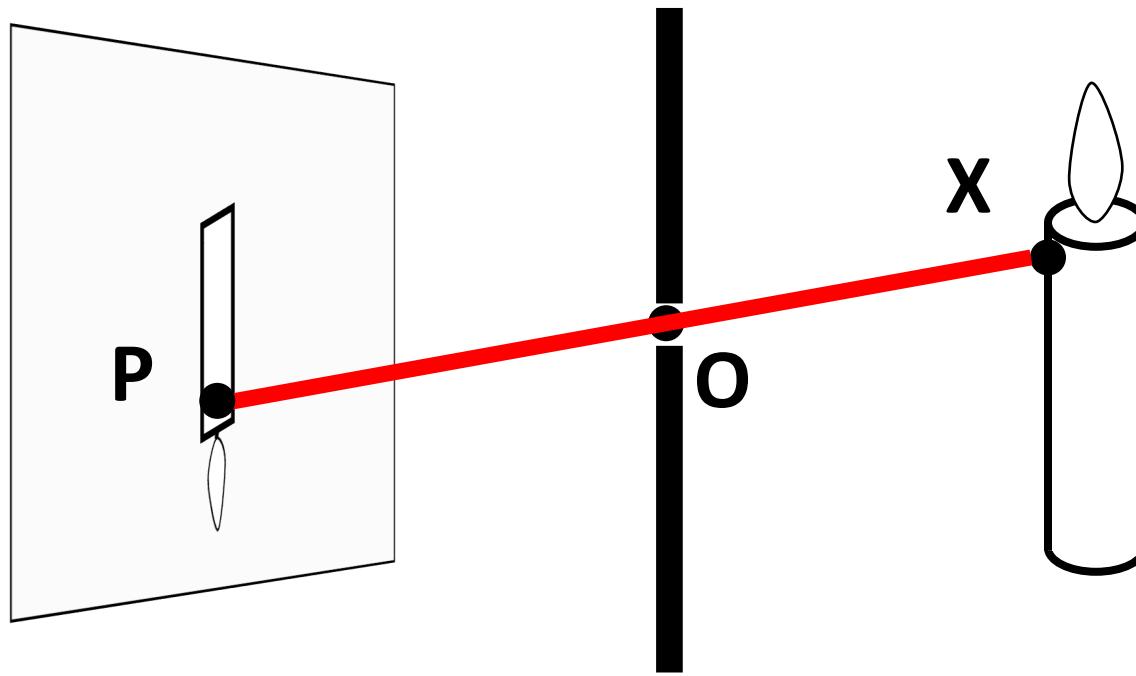


Justin on 8/21/2017

Projection



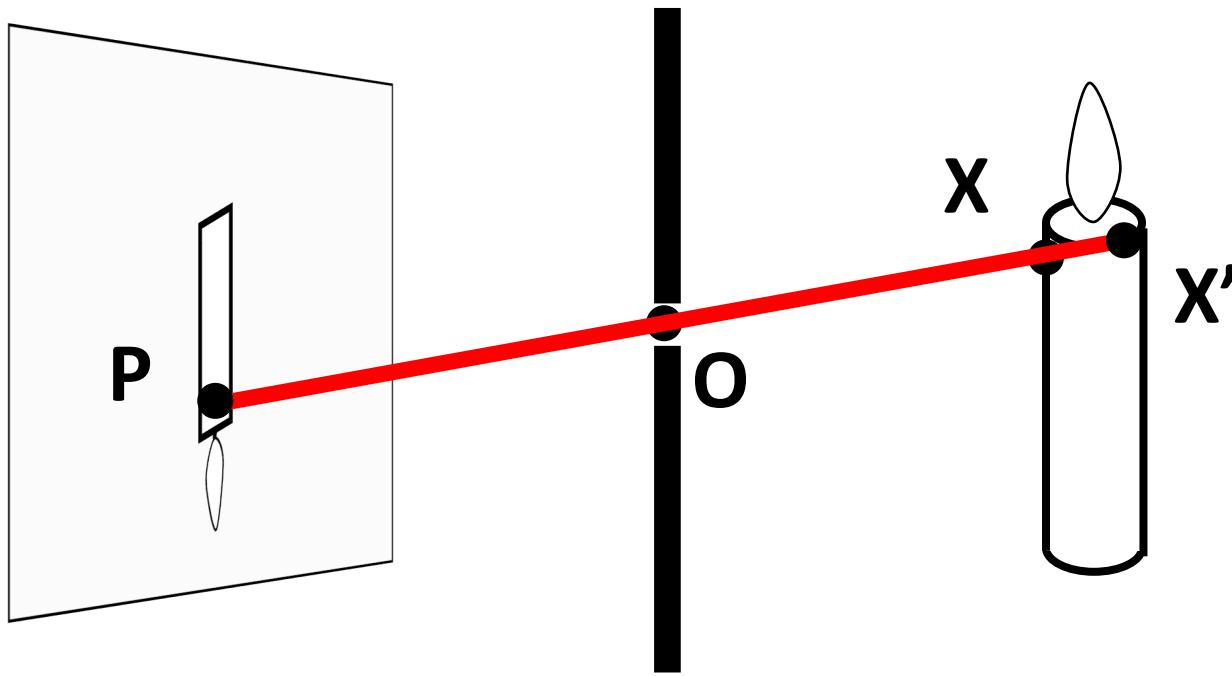
Projection



How do we find the projection P of a point X ?

Form visual ray from X to camera center and intersect it with camera plane

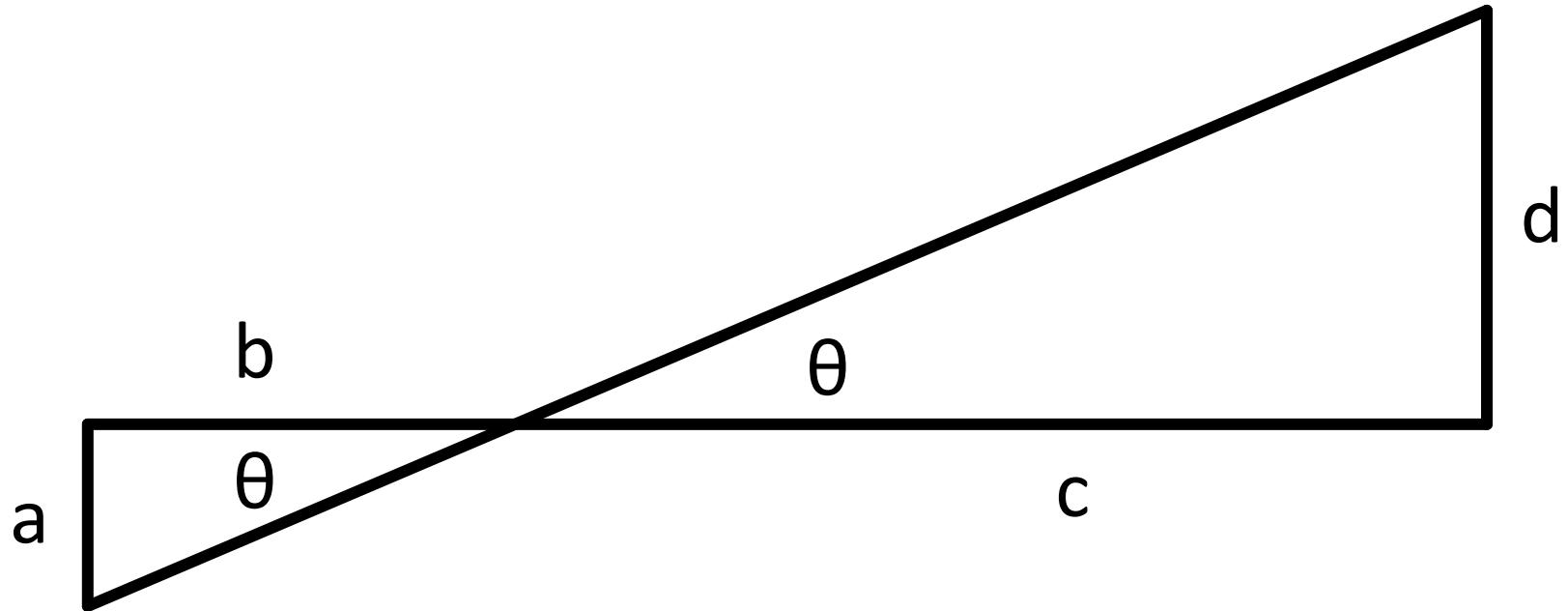
Projection



Both X and X' project to P. Which appears in the image?

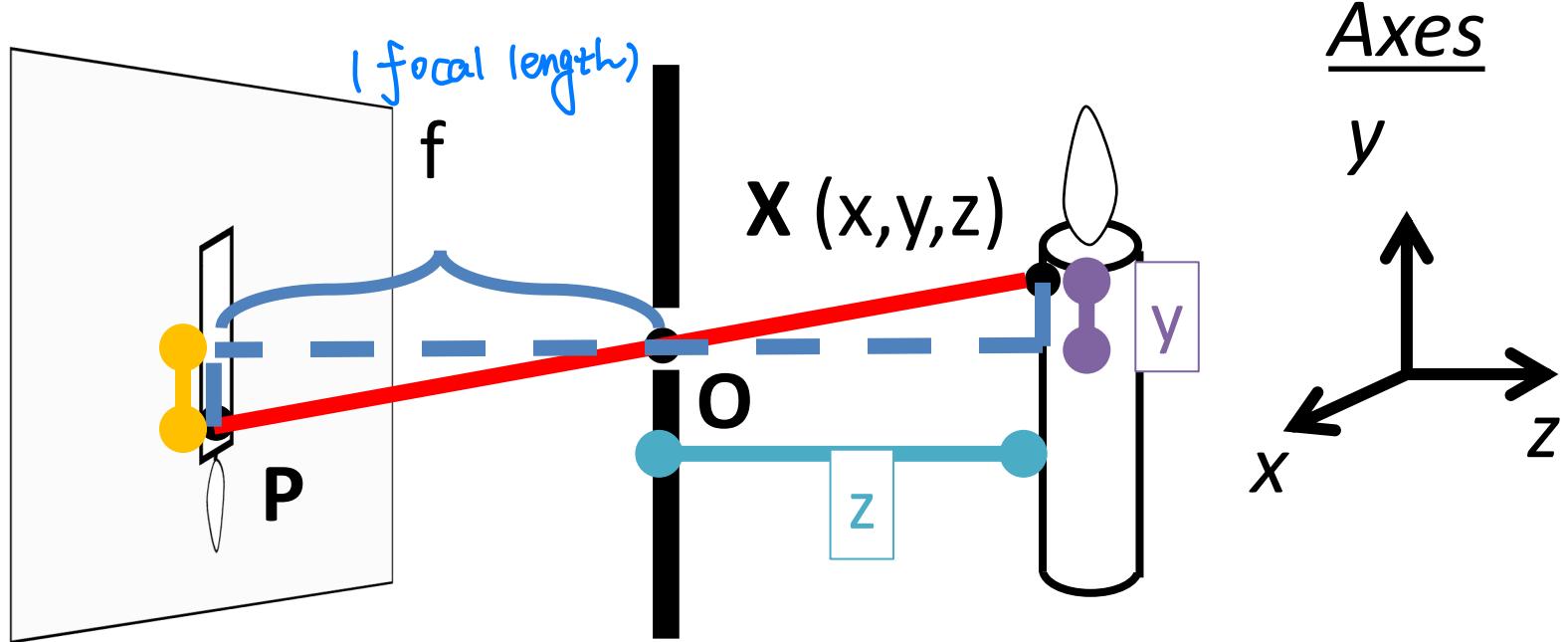
Are there points for which projection is undefined?

Quick Aside: Remember This?



$$\frac{a}{b} = \frac{d}{c} \longrightarrow a = \frac{bd}{c}$$

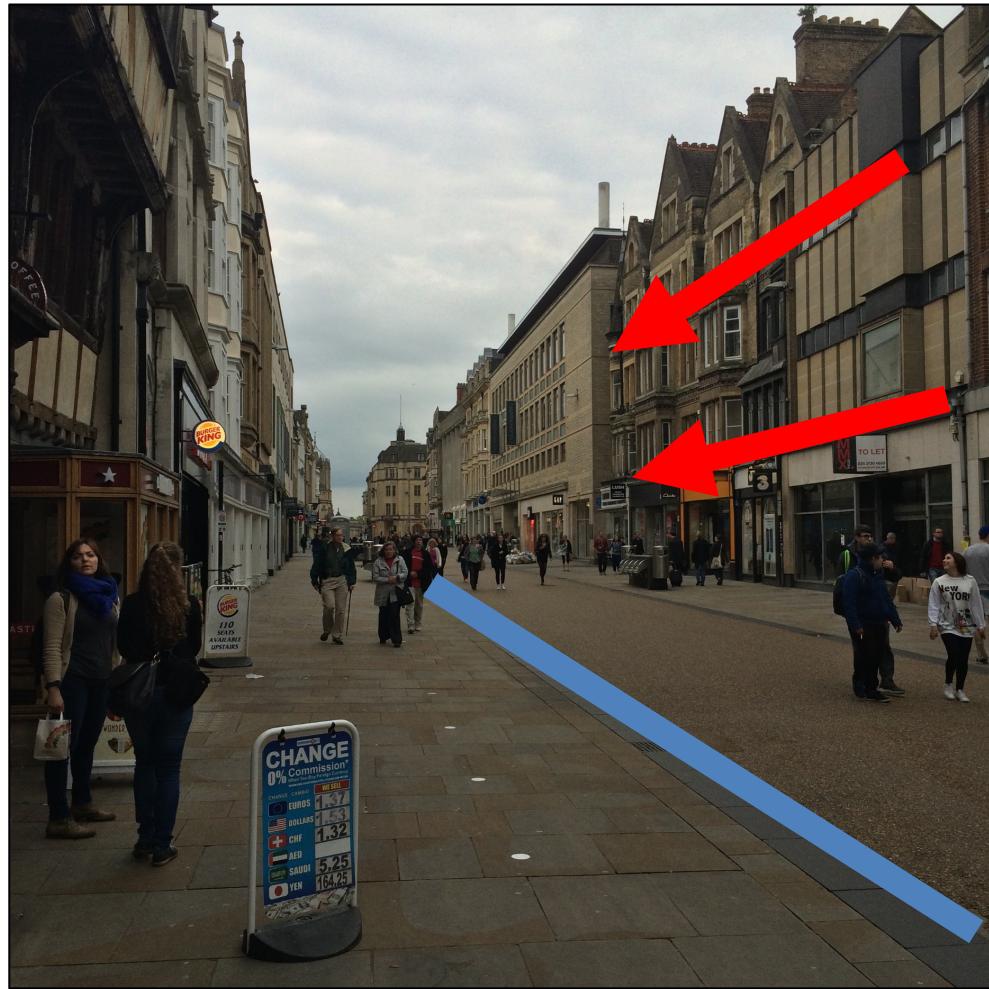
Projection Equations



Coordinate system: O is origin, XY in image, Z sticks out.
 XY is image plane, Z is optical axis.

(x, y, z) projects to $(fx/z, fy/z)$ via similar triangles

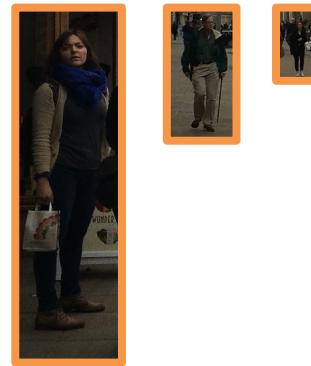
Some Facts About Projection



3D lines project to 2D lines

The projection of any 3D parallel lines converge at a vanishing point

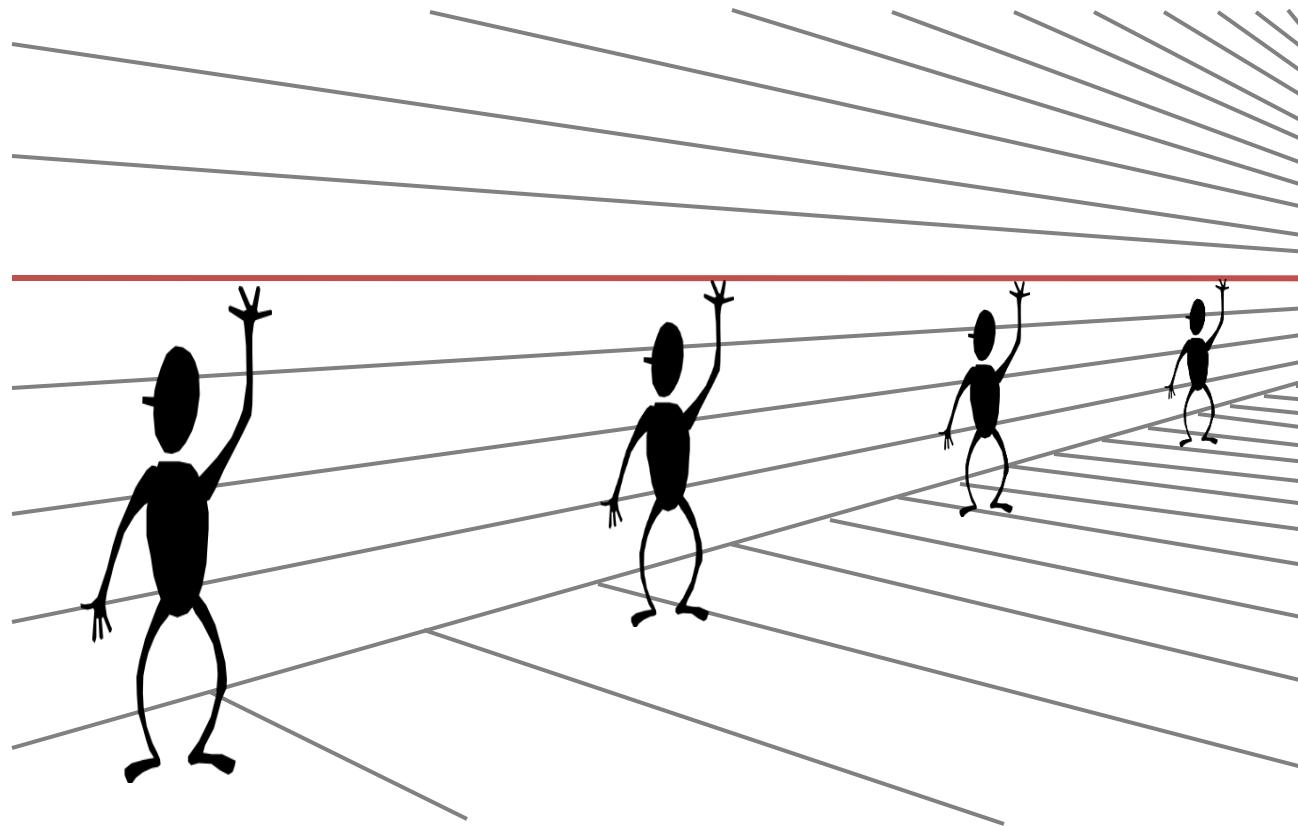
Distant objects are smaller



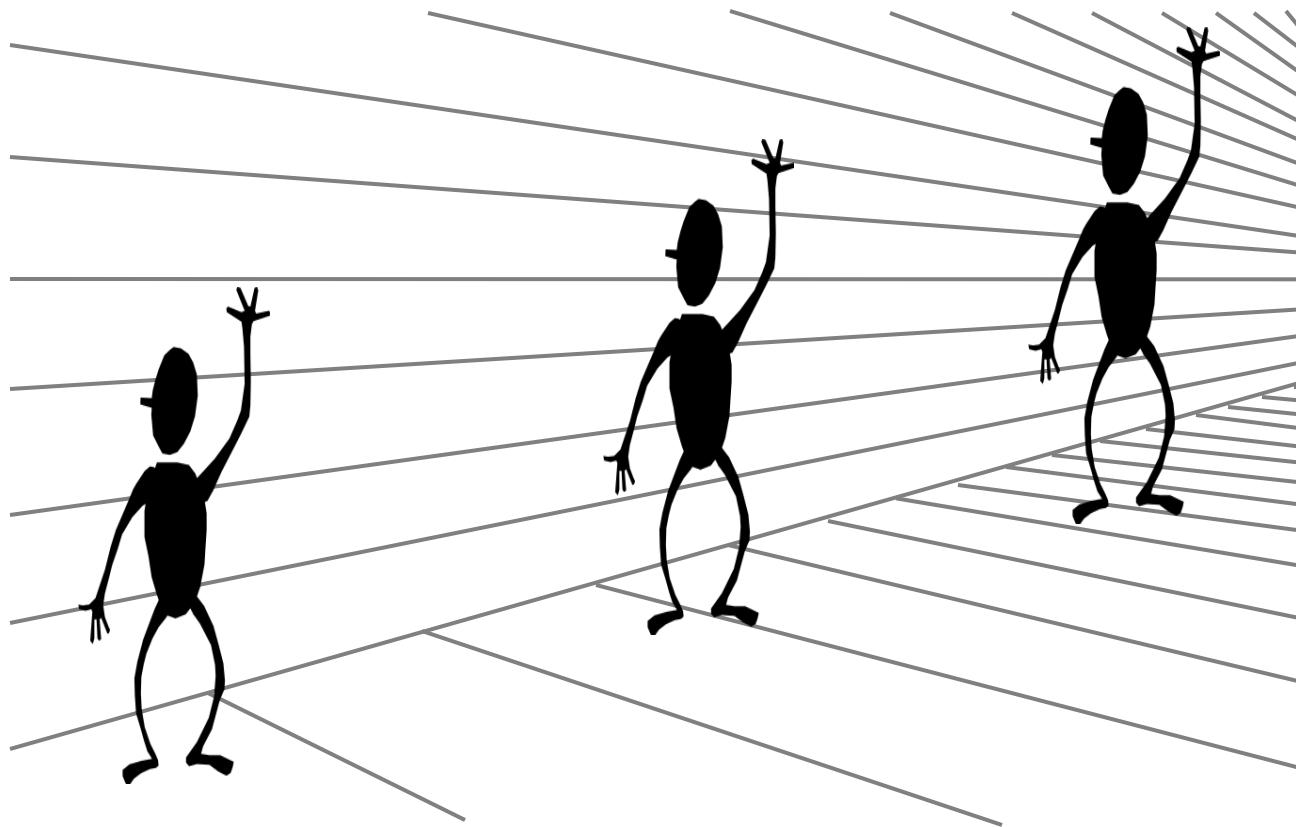
Some Facts About Projection

Let's try some fake images

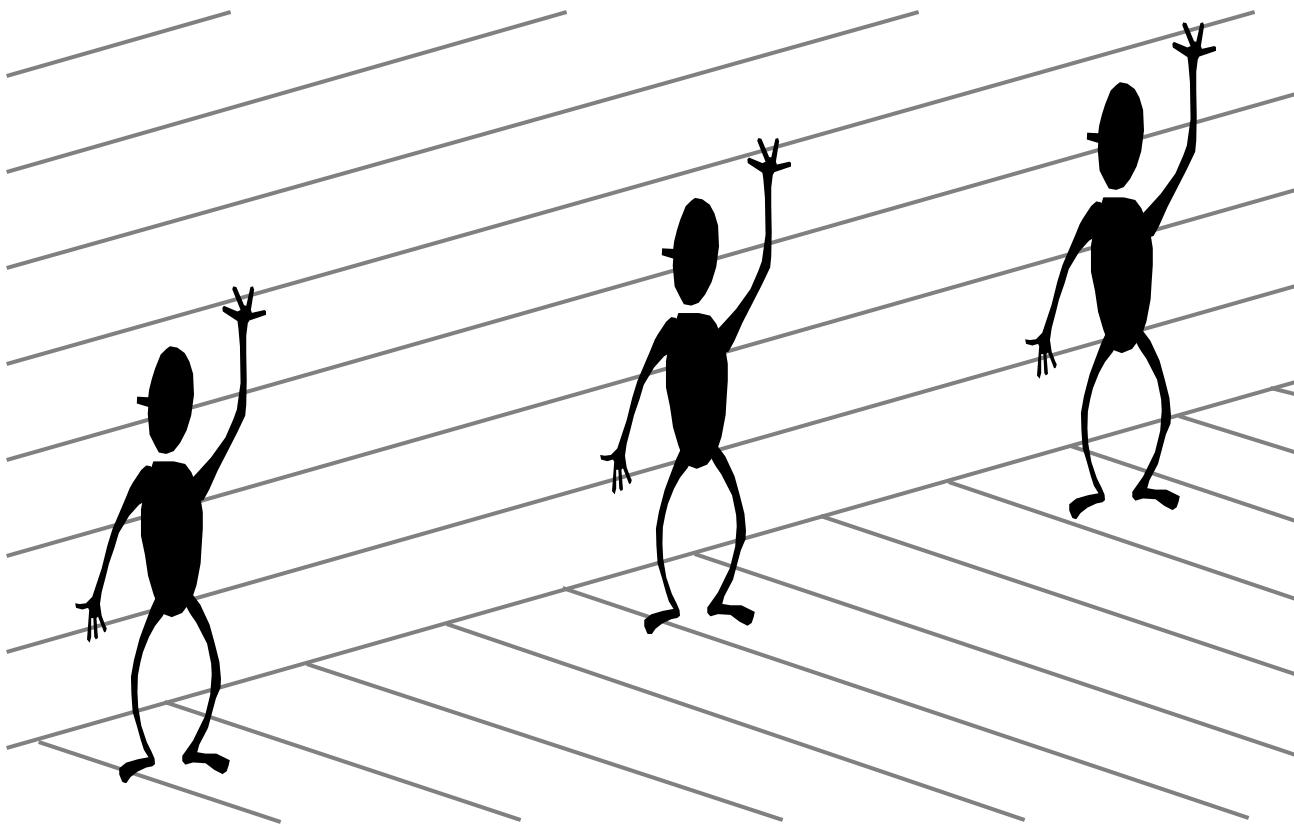
Some Facts About Projection



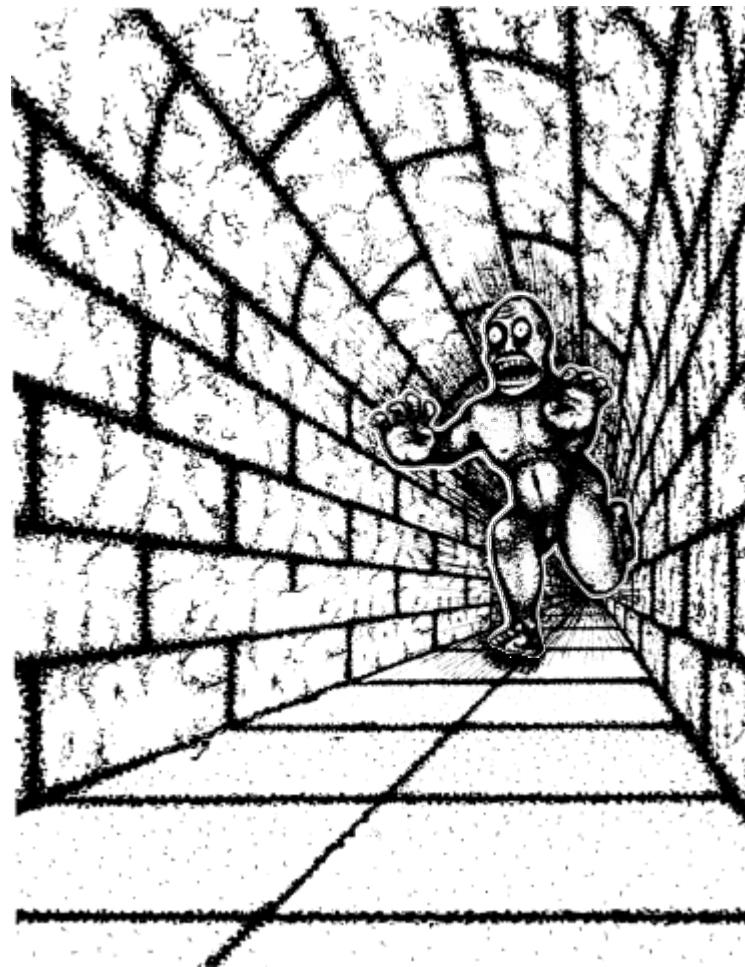
Some Facts About Projection



Some Facts About Projection

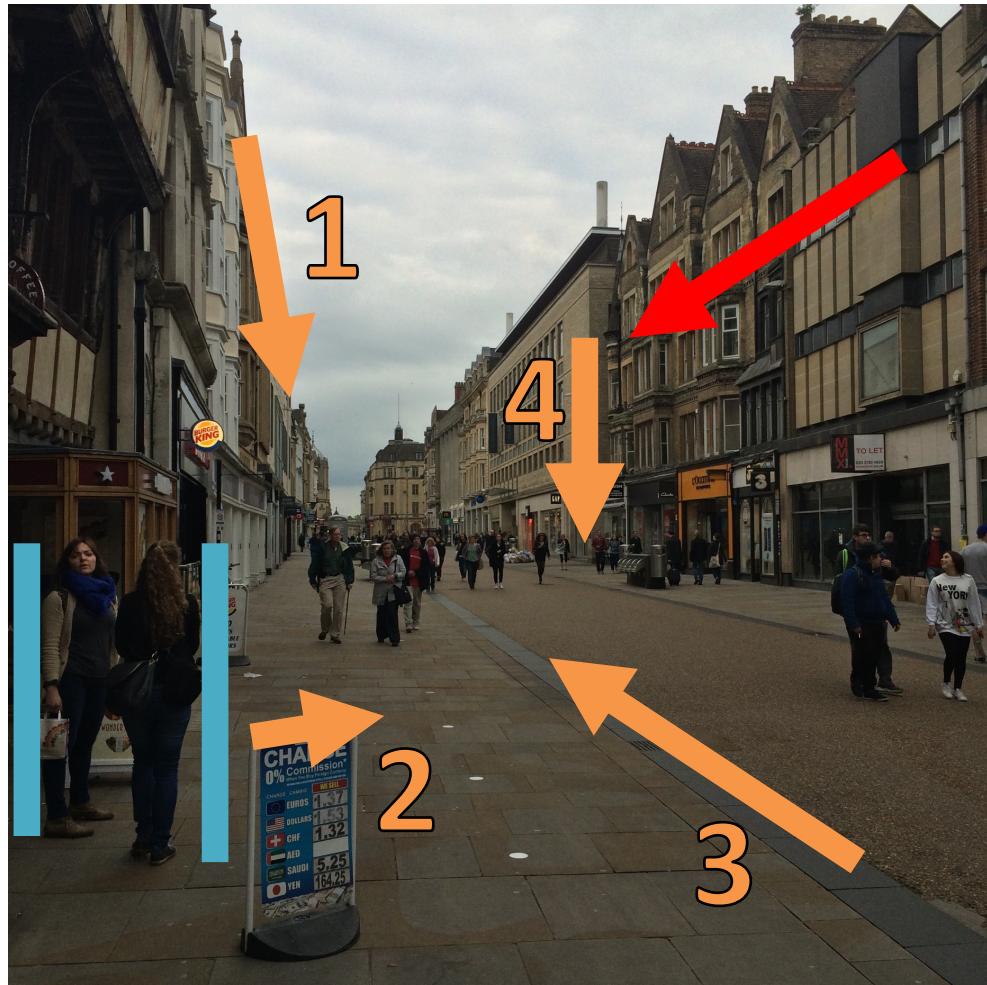


Some Facts About Projection



Illusion Credit: RN Shepard, Mind Sights: Original Visual Illusions, Ambiguities, and other Anomalies

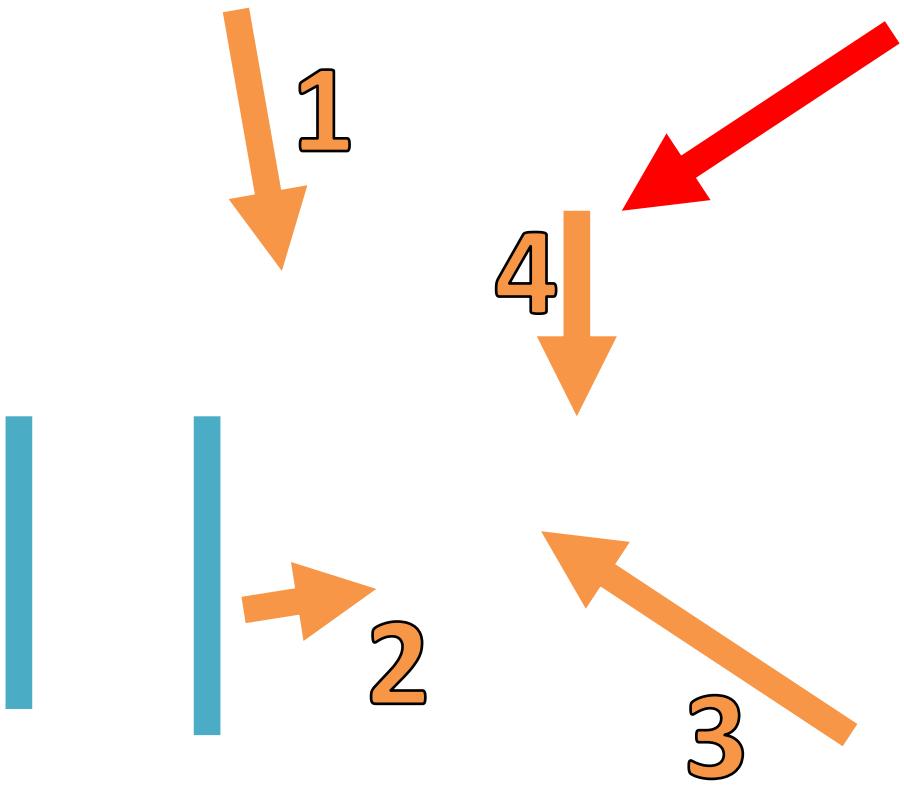
What's Lost?



Is she shorter or further away?

Are the orange lines we see parallel / perpendicular / neither to the red line?

What's Lost?



Is she shorter or further away?

Are the orange lines we see parallel / perpendicular / neither to the red line?

What's Lost?

Be careful of drawing conclusions:

- Projection of 3D line is 2D line; NOT 2D line is 3D line.
- Projections of parallel 3D lines converge at VP; NOT any pair of lines that converge are parallel in 3D.
- **Can you think of a counter-example?**

